

Heat flow rate at a bore-face and temperature in the multi-layer media surrounding a borehole

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Abstract

Assessment of the heat either delivered from high temperature rocks to the borehole or transmitted to the rock formation from circulating fluid is of crucial importance for a number of technological processes related to borehole drilling and exploitation. Normally the temperature fields in the well and surrounding rocks are calculated numerically by finite difference method or analytically by applying the Laplace-transform method. The former approach requires tedious and, in certain cases, non-trivial numerical computations. The latter method leads to rather bulky formulae that are inconvenient for further numerical evaluation. Moreover, in previous studies where the solution is obtained analytically, the heat interaction of the circulating fluid with the formation was treated on the condition of constant bore-face temperature. In the present study the temperature field in the rock formation disturbed by the heat flow from the borehole is modeled by a heat conduction equation, assuming the Newton model for the convective heat transfer on the bore-face, with boundary conditions that account for the thermal history of the borehole exploitation. The problem is solved analytically by the generalized heat balance integral method. Within this method the approximate solution of the heat conduction problem is sought in the form of a finite sum of functions that belong to a complete set of linearly independent functions defined at the finite interval bounded by the radius of thermal influence and that satisfy the homogeneous boundary conditions on the bore-face. In the present study first and second order approximations are obtained for the composite multi-layer domain. The numerical results illustrate that the second approximation is in a good agreement with the exact solution. The only disadvantage of this solution is that it depends on the radius of thermal influence, which is an implicit function of time and can only be found numerically by iterative algorithms. In order to eliminate this complication, in this study an approximate explicit formula for the radius of thermal influence and new close-form approximate solution are proposed on the basis of the approximate solution obtained by the integral-balance method. Employing the non-linear regression method the coefficients for this simplified solution are obtained. The accuracy of the approximate solution is validated by comparison with the exact analytical solution found by Carslaw and Jaeger for the homogeneous domain. © 2003 Elsevier Ltd. All rights reserved.

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Keywords

Approximate solution, Bore-face, Borehole, Casing, Formation, Heat flux, Temperature